MYCOTAXON
ISSN (print) 0093-4666 (online) 2154-8889 Mycotaxon, Ltd. ©2018

October–December 2018—Volume 133, pp. 681–701
https://doi.org/10.5248/133.681

A preliminary study of the yellow *Acarospora* of China

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Abstract—The four species of yellow *Acarospora* recorded from China (*A. fulva, A heufleriana, A. schleicheri*, and *A. stapfiana*) are described in detail from specimens collected in the Xinjiang region of central Asia. *Acarospora fulva* and *A. stapfiana* are reported as new for China. A key to species of yellow *Acarospora* in China is provided. Sequences of three species from this study have been deposited in GenBank.

Key words—*Acarosporaceae,* biodiversity, rhizocarpic acid, taxonomy

Introduction

In *Lecanoromycetes* O.E. Erikss. & Winka, Subclass *Acarosporomycetidae* V. Reeb & al. was proposed by Reeb & al. (2004) for a single order *Acarosporales* V. Reeb & al. and containing a single family of lichenized and non-lichenized lichenicolous fungi, *Acarosporaceae* Zahlbr. (Jaklitsch & al. 2016, Miadlikowska & al. 2014). *Acarosporomycetidae,* recognized as one of the oldest lichenized fungal taxa, are thought to have diverged from other lecanoromyceteous lineages during the Carboniferous period 299–365 million years ago (Prieto & Wedin 2013). Its species characterized by polyspored asci and a green alga photobiont, are crustose lichens that occur on rock and soil, often as pioneers and usually in arid habitats (Magnusson 1929). The family currently contains over 400 taxa, but due to taxonomic and nomenclatural problems and the lack of a modern global revision, a calculation of the exact number of species is not possible (http://www.indexfungorum.org). Seven genera are now represented: *Acarospora* A. Massal., *Glypholecia* Nyl., *Myriospora* Nägeli ex Uloth, *Pleopsidium* Körb., *Sarcogyne* Flot., *Timdalia* Hafellner, and *Trimmathelopsis* Zschacke (Arcadia & Knudsen 2012, Knudsen & Lendemer 2016, Westberg & al. 2015). The genera *Polysporina* Vězda and *Thelocarpella* Nav.-Ros. & Cl. Roux were found to be paraphyletic, and their taxa have been transferred to other genera (Knudsen & Lendemer 2016, Westberg & al. 2015).

Yellow species of *Acarospora, Pleopsidium,* and *Sarcogyne* have been reported from around the world (Costello & Nimis 1994, Hafellner 1993, Knudsen 2007, McCarthy & Elix 2017, Magnusson 1929, 1956). One hundred and two species of *Acarosporaceae* have a yellow cortex (Costello & Nimis 1994; Golubkova 1979; Knudsen 2007; Knudsen & al. 2008; Knudsen & Elix 2008; Knudsen & Flakus 2009, 2016; Lumbsch & al. 2011; McCarthy & Elix 2017; Magnusson 1929, 1956; Øvstedal & al. 1918; Roux & Wirth 2011). The yellow color is from rhizocarpic acid and/or epanorin. Epanorin occasionally occurs with rhizocarpic acid in major or minor concentrations in some species or may replace rhizocarpic acid (e.g., in *A. congregata* K. Knudsen & Flakus in South America; Knudsen & al. 2008, Knudsen & Flakus 2016). Both secondary metabolites are derived from pulvinic acid as are calycin and pinastric acid commonly found in yellow species of *Chrysotrix* and *Candelariella* (Huneck & Yoshimura 1996). Rhizocarpic acid allows growth of yellow *Acarosporaceae* in dry habitats with high sunlight and extreme temperatures and on nutrient poor acidic or calcareous substrates in deserts and mountains as well as south slopes in temperate habitats (Hauck & al. 2010, Meeßen & al. 2013, Rubio & al. 2002).

Magnusson (1929) proposed *Acarospora* subg. *Xanthothallia* H. Magn. for yellow *Acarospora,* but molecular phylogenies do not support yellow species within a monophyletic group (Leavitt & al. 1918, Reeb & al. 2004, Westberg & al. 2015). *Acarospora* subg. *Xanthothallia* is considered an artificial taxon and no longer accepted.

Studying collections of *Acarosporaceae* from Gansu in China, Magnusson reported one yellow species, *Pleopsidium gobiense* (H. Magn.) Hafellner (Magnusson 1940; as *Acarospora gobiensis* H. Magn.). Magnusson reported five yellow species from Southern Mongolia: *P. discurrens* (Zahlbr.) Obermayer (as *A. discurrens*), *P. gobiense, A. heufleriana*, *A.* cf. *congregata* (as *Acarospora* cf. *xanthophana*), and *A. schleicheri* (Magnusson 1944). Russian lichenologist Golubkova (1988) reported seven species from central Asia in U.S.S.R.: *Pleopsidium chlorophanum* (Wahlenb.) Zopf (as *A. chlorophana*), *P. flavum* (Bellardi) Körb. (as *Acarospora oxytona*), *P. gobiense, A. heufleriana,* *A. schleicheri, A. stapfiana,* and *A. sulphurata* (Arnold) Arnold. *Pleopsidium discurrens* was reported from Tibet (Obermayer 1996), and additional records of *P. chlorophanum, P. discurrens, P. flavum,* and *P. gobiense* were reported from China by Niu & al. (2015, 2017).

Eight yellow representatives of *Acarosporaceae* occur in China: four *Acarospora* species and four *Pleopsidium* species. In this paper we report four yellow *Acarospora* species for China from the Xinjiang region of central Asia: *A. heufleriana* and *A. schleicheri* (Wei 1991) as well as *A. fulva* and *A. stapfiana,* which are reported here from China for the first time.

Material & methods

The examined specimens are preserved in Arid Land Lichen Research Center of Western China, Xinjiang University, Urumqi, China (XJU-NALH). They were morphologically examined with Olympus STM7 microscope and photographed with Nikon DS-Fi2 and Canon PC1200 cameras. Measurements were made in water and the hymenial gel was tested for amyloidity with Lugol's (IKI). Spot tests were made for norstictic acid with potassium hydroxide (KOH) and for gyrophoric acid with potassium hydroxide and sodium hypochlorite (KC). Sequences from specimens in this study representing *A. fulva, A heufleriana,* and *A. stapfiana* were deposited in GenBank and used by Øvstedal & al. (2018) in their phylogeny of yellow *Acarospora*.

Taxonomy

Acarospora fulva N.S. Golubk., Nov. Sist. Niz. Rast. 16: 130 (1979). FIG. 1E, F

THALLUS areolate, contiguous, at first flat then convex, rugulose, with deep cracks between areoles, round to irregular; areoles eventually forming stipes and becoming squamulose, 0.5–3 mm wide, 0.4–0.8 mm high, rim down-turned, sometimes blackish or concolorous with upper surface. Upper surface yellow, becoming greenish yellow when wet, fissured, epruinose; lower surface corticated, and yellow, brownish yellow, or blackish. Cortex 40–65 µm thick, paraplectenchymatous to prosoplectenchymatous, cells varying in size. Algal layer uneven, interrupted by hyphal bundles, ≤150 µm thick, algal cells 5–14 µm in diam. Medulla white, prosoplectenchymatous, ≤450 µm thick.

APOTHECIA immersed, punctiform at first, then expanded, usually one per areole, varying in shape, 0.3–1.2 mm wide, disc blackish brown, sometimes with a yellow umbo, rough, fissured. Parathecium hyaline, distinct, 15–25 µm wide, expanded, ≤75 µm around the disc. Epihymenium yellowish brown, 10–20 µm tall. Hymenium hyaline, interascal gel I+blue turning red (hemiamyloid), 50–85 µm tall, paraphyses 2–3 µm diam, apices brownish black, expanding to 4 µm diam. Asci clavate, 40–72 × 6–15 µm, with about 100 ascospores,

ascospores various in size, hyaline, simple, 3.5–6 × 1.8–3 µm. Subhymenium 30–50 µm tall. Hypothecium 35–65 µm tall.

SPOT TESTS: cortex C+ red, KC+ red. SECONDARY METABOLITES: gyrophoric acid, rhizocarpic acid. ITS SEQUENCES: MF134868, MF134867.

SELECTED SPECIMENS EXAMINED: CHINA. INNER MONGOLIA. **Baotou**, alt. 1535 m, 6 August 2014, A. Abbas, G. Sahedat, L. Nurtai 20141065a, 20141065b, 20141062b (GenBank MF134867), 20141080, 20141058 (XJU-NALH). XINJIANG. **Altay Mountain**, alt. 1075 m, 5 May 2014, A. Abbas 2014050a, 2014051a, 2014052a (XJU-NALH); **Qinghe**, alt. 1299 m, 17 June 2013, A. Abbas 20130706a (XJU-NALH); alt. 1294 m, 17 June 2013, A. Abbas 20130707b, 201306af (XJU-NALH); alt. 1290 m, 17 June 2013, A. Abbas 20130627, 20130808 (XJU-NALH); **Turhong Township**, alt. 1470 m, 21 July 2012, A. Abbas 20122442, 20122500 (XJU-NALH).

ECOLOGY & DISTRIBUTION. Occurs on siliceous rock. Endemic to central Asia (China, Mongolia); this is a new species record for China.

DISCUSSION. The species is easily identified with spot tests. Only four other yellow *Acarospora* species with gyrophoric acid have been described: *A. ramosa* K. Knudsen & Flakus from South America (Knudsen & Flakus 2009), and *A. erythrophora* H. Magn., *A. robiniae* K. Knudsen, and *A. tuckerae* K. Knudsen from North America (Knudsen 2007). *Acarospora fulva* has a lower hymenium than *A. erythrophora* (100–170 µm; Knudsen 2007); a lower hymenium and thinner upper cortex than *A. robiniae* (hymenium, 80–120 µm; cortex, 80–100 µm; Knudsen 2007); and a lower hymenium than *A. ramosa* (150–180 µm; Knudsen & Flakus 2009). The algal layer of *A. tuckerae* is even and only the medulla is C+ red with gyrophoric acid, whereas that of *A. fulva* is jagged and interrupted by hyphal bundles, and the cortex is C+ red with gyrophoric acid (Knudsen 2007). Golubkova (1988) referred the earlier report of *A.* cf. *congregata* (Magnusson 1944, as *A.* cf. *xanthophana*) to *A. fulva*.

Acarospora heufleriana Körb., Parerga Lichenol. 1: 57 (1859). FIG. 1A–D

THALLUS areolate, contiguous to dispersed, flat, broadly attached to the substratum, areoles angular, 0.3–1.5 mm wide, 250–320 µm high. Upper surface greenish yellow to yellow, yellowish gray when pruinose, usually smooth and glossy when epruinose, or cracking. Cortex 50–90 µm thick, with round cells, the cells 4–7 µm in diam. Algal layer even to uneven, sometimes interrupted by hyphal bundles, cells 7.5–17 µm in diam. Medulla white, prosoplectenchymatous, hyphae anti-clinal, ≤250 µm thick.

APOTHECIA 1–3 per areoles, smooth immersed, round or irregular, disc dark brown to brown or yellowish, rough, epruinose. Parathecium 25–45 µm wide. Epihymenium yellow, 5–10 µm tall. Hymenium hyaline to yellowish,

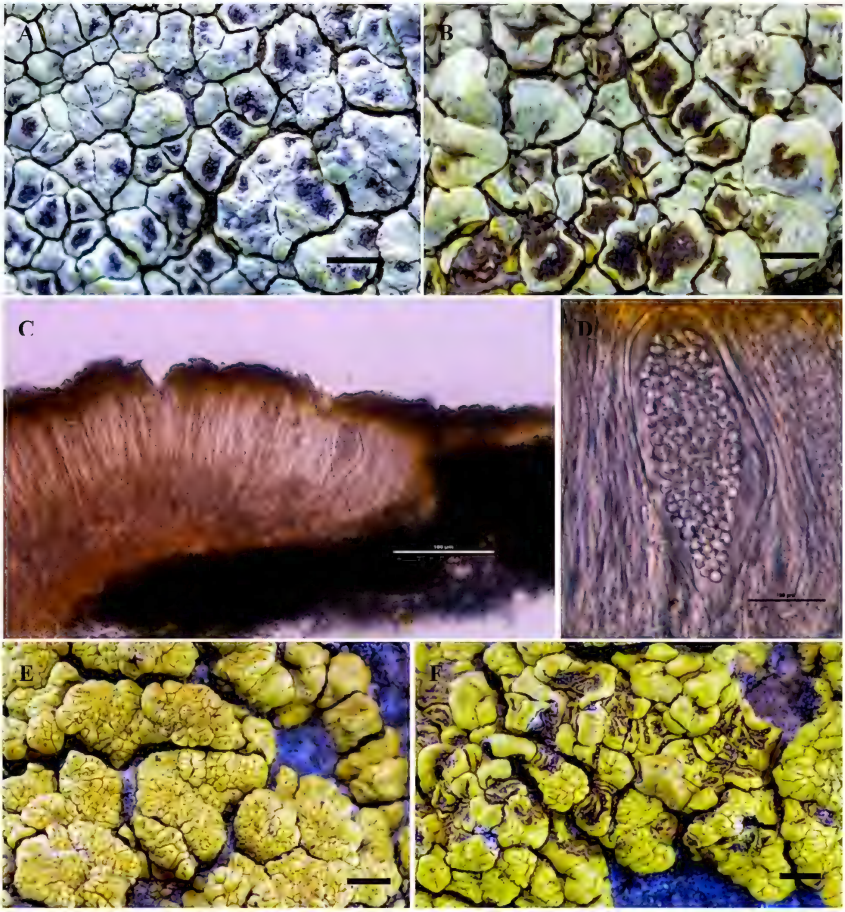

Fig. 1. ***Acarospora heufleriana*** (XJU-NALH.20141106): A, B. Thallus and apothecia; C, D. Cross section of apothecia and ascus. ***Acarospora fulva*** (XJU-NALH.2014050a): E, F. Thallus and apothecia. Scale bars: A, B, E, F = 1 mm; C = 100 µm; D = 20 µm.

interascal gel I+ greenish blue turning red (hemiamyloid), 92–120 µm tall. Asci clavate, with 100–200 ascospores, 81–110 × 17–28 µm; ascospores hyaline, simple, ellipsoid, 3.5–5.0 × 2–2.8 µm. Subhymenium 30–40 µm tall, I+ blue, hypothecium yellowish, 25–45 µm tall.

Spot test: medulla K+ red (forming distinct crystals). Secondary metabolites: rhizocarpic acid, norstictic acid. ITS sequence: MF134874.

Specimens examined: **CHINA. Inner Mongolia. Daqingshan**, alt. 1255 m, 1 August 2014, A. Abbas, G. Sahedat, L. Nurtai 20141105a, 20141105b, 20141105c, 20141130b, 20141090b, 20141090c, 20141107, 20141108, 20141090a, 20141106, 20141130a (XJU-NALH); alt. 1719 m, 1 August 2014, A. Abbas, G. Sahedat, L. Nurtai 20141147 (XJU-NALH); **Mount Huaguo**, alt. 1535 m, 6 August 2014, A. Abbas, G. Sahedat, L. Nurtai 20141072b, 20141072a (GenBank MF134874), 20141075 (XJU-NALH).

Ecology & distribution. On siliceous rock. Asia (Magnusson 1944, Golubkova 1988), Europe (Magnusson 1929), North America (Knudsen 2007).

Discussion. *Acarospora heufleriana* produces the secondary metabolite norstictic acid and is easily identified with spot tests. Two other yellow *Acarospora* species with norstictic acid have been reported from North America (Knudsen 2007). *Acarospora calcarea* K. Knudsen differs from *A. heufleriana* primarily in being effigurate (not effuse), and *A. rouxii* K. Knudsen & al. is distinguished by its higher (100–170 µm) hymenium.

Acarospora schleicheri (Ach.) A. Massal.,
Ric. Auton. Lich. Crost.: 27 (1852). Fig. 2 c, d, g

Thallus areolate to squamulose, contiguous, broadly attached to the substratum by rhizohyphae, upper surface pruinose to epruinose, rough or smooth, dull, squamules 0.3–2.7(–3.2) mm wide, ≤270 µm thick. Cortex 40–80 µm thick, paraplectenchymatous to prosoplectenchymatous. Algal layer uneven, interrupted by hyphal bundles, ≤130 µm thick. Medulla white, prosoplectenchymatous, hypha thin-walled, ≤200 µm thick.

Apothecia immersed, round to irregular, disc blackish brown or brown or yellowish, rough, pruinose to epruinose. Parathecium indistinct. Epihymenium yellowish brown, 10–18 µm tall. Hymenium hyaline, with crystals, I+ blue (amyloid), 80–130 µm tall, paraphyses 1–2.3 µm diam, apices expanded ≤5 µm. Asci clavate, with 100+ ascospores; ascospores broadly ellipsoid or subglobose, with one or two oil spots, hyaline, simple, 3–7 × 2–4.5 µm. Subhymenium hyaline, 30–55 µm. Hypothecium indistinct.

Spot tests: negative. Secondary metabolites: rhizocarpic acid.

Selected specimens examined: **CHINA. Tibet. Lasa**, alt. 4731 m, 24 September 2012, Wen 20120924 (XJU-NALH); alt. 4960 m, 24 September 2012, Wen 20120925 (XJU-NALH); alt. 4432 m, 10 September 2011, Wen 20110910 (XJU-NALH).

Ecology & distribution. *Acarospora schleicheri* is quite common in the Northern Hemisphere, reported from central Asia (Abbas & Wu 1998, Golubkova 1988, Magnusson 1944), Europe, North Africa, and North America (Magnusson 1929).

Discussion. *Acarospora schleicheri* is an obligate terricolous lichen with distinct rhizohyphae that bind and hold together soil crusts. It occurs on both

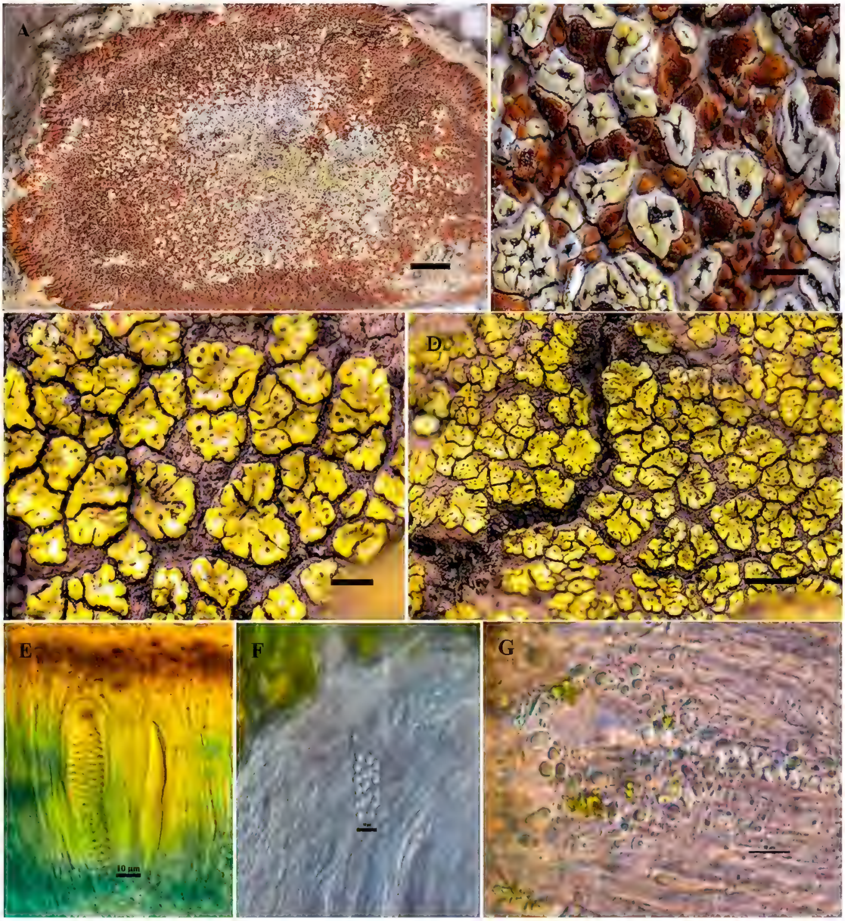

Fig. 2. ***Acarospora stapfiana*** (XJU-NALH 20110389): A, B. Thallus and apothecia; E, F. Ascus after iodine reaction and spherical ascospores. ***Acarospora schleicheri*** (XJU-NALH 20120924): C, D. Thallus and apothecia; G. Ascospores. Scale bars: A–D = 1 mm; E–G = 10 µm

calcareous and non-calcareous soils and spreads both through division of squamules and through spreading rhizohyphae, which form new squamules sometimes several centimeters from main thallus. It has been reported as a parasite on other lichens; its rhizohyphae penetrate other lichens (such as *Diploschistes muscorum* (Scop.) R. Sant.) in soil crusts from below and destroy them as it forms new squamules. It is not an obligate parasite but an opportunistic parasite in competition for space and may not even steal the algae of the host, as probably is the case in most lichenicolous lichens.

Acarospora stapfiana (Müll. Arg.) Hue,
Nouv. Arch. Mus. Hist. Nat., Paris, 5 sér., 1: 161 (1909). FIG. 2A, B, E, F

THALLUS areolate to subsquamulose, contiguous, little dispersed, parasitic on *Caloplaca* species, areoles round. Upper surface greenish yellow to yellow, or gray when pruinose, smooth to cracked, 0.3–1.7 mm wide, ≤900 μm high. Cortex 45–70 μm thick, paraplectenchymatous to prosoplectenchymatous. Algal layer even, ≤205 μm thick, cells 5–15 μm diam. Medulla white, prosoplectenchymatous, ≤380 μm thick.

APOTHECIA 1–3 per areole, with radial fissures around apothecia, punctiform at first, then immersed, round, disc reddish brown, rough, epruinose. Parathecium 8–30 μm wide. Epihymenium reddish brown, 15–25 μm tall. Hymenium hyaline, 90–110 μm tall, I+ dark blue, paraphyses 1.5–2.5 μm diam, apices expanded and brown, ≤4.5 μm. Asci clavate, with 100+ ascospores, 56–65 × 17–20 μm; ascospores globose or broadly ellipsoid, hyaline, simple, 3–5 × 3–4 μm Subhymenium indistinct 20–35 μm tall, hypothecium hyaline, 15–25 μm tall.

SPOT TEST: negative. SECONDARY METABOLITES: rhizocarpic acid. ITS SEQUENCES: MF134871, MF134870.

SPECIMENS EXAMINED: **CHINA. XINJIANG. Aktau**, alt. 4320 m, 1 August 2011, A. Abbas 20110389 (XJU-NALH; GenBank MF134870): **Shirengou**, alt. 1543 m, 25 November 2013, A. Abbas, L. Nurtai, G. Nazarbek 20130040 (XJU-NALH; GenBank MF134871); **Wucaiwan**, alt. 2070 m, 4 June 2011, A. Abbas AS110604 (XJU-NALH); **Altin Mountain**, alt. 4000 m, 14 July 2005, A. Abbas 500110 (XJU-NALH).

ECOLOGY & DISTRIBUTION. Usually on calcareous rock, parasitic on orange saxicolous *Caloplaca* species in Asia (Golubkova 1988, Magnusson 1929, 1944) and North America (Knudsen 2007); this is a new record for China.

DISCUSSION. *Acarospora stapfiana* is a lichenicolous lichen and obligate parasite. It begins its life cycle as a juvenile non-lichenized fungus within various *Caloplaca* species. It destroys the orange host, probably stealing its algal photobiont, and progressively morphs out of the host forming its own yellow lichenized thallus (Knudsen 2007).

A key to yellow *Acarospora* in China

1. Ascus tholus with I+ blue cylinder around ocular chamber (Hafellner 1993, Obermayer 1996) . . . . [*Pleopsidium*]
[See Niu & al. 2017 for descriptions and key to Chinese material.]
1. Ascus tholus I– 2

2. On soil . . . . *A. schleicheri*
2. On rock 3

3. Cortex C+ red, thallus usually forming a stipe .... *A. fulva*
3. Cortex and medulla C– 4

4. Medulla K+ red, not parasitic on *Caloplaca* species .... *A. heufleriana*
4. Medulla K–, parasitic on *Caloplaca* species .... *A. stapfiana*

Acknowledgements

We thank Dr. Shouyu Guo (Institute of Microbiology, Chinese Academy of Science, Beijing) and Dr. Pamela Rodriguez-Flakus (W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow) for presubmission review. The work of Abdulla Abbas was financially supported by National Science Fund of China (2013FY110400, 31670023). The work of Kerry Knudsen was financially supported by the grant "Environmental Aspects of Sustainable Development of Society" 42900/1312/3166 from the Faculty of Environmental Sciences, Czech University of Life Sciences, Prague.

Literature cited

Abbas A, Wu J. 1998. Lichens of Xinjiang. Urumqi: Sci-Tech & Hygiene Publishing House of Xinjiang, 130 p.

Arcadia L, Knudsen K. 2012. The name *Myriospora* is available for the *Acarospora smaragdula* group. Opuscula Philolichenum 11: 19–25.

Costello M, Nimis PL. 1994. Critical notes on Antarctic yellow *Acarosporaceae*. Lichenologist 26(3): 283–294.

Golubkova NS. 1979. *Acarospora fulva* Golubk. species lichenis nova in Mongolia inventa. Novitates Systematicae Plantarum non Vascularium (Academia Scientiarum URSS, Institutum Botanicum Nomine V. L. Komarovii) 16: 129–133.

Golubkova NS. 1988. The lichen family *Acarosporaceae* in the U.S.S.R. Leningrad: Nauka. 136 p.

Hafellner J. 1993. *Acarospora* und *Pleopsidium* – zwei lichenisierte Ascomycetengattungen (*Lecanorales*) mit zahlreichen Konvergenzen. Nova Hedwigia 56(3-4): 281–305.

Hauck M, Jürgens SR, Leuschner C. 2010. Effect of amino acid moieties on metal binding in pulvinic acid derivatives and ecological implications for lichens producing these compounds. Bryologist 113(1): 1–7. https://doi.org/10.1639/0007-2745-113.1.1.

Huneck S, Yoshimura I. 1996. Identification of lichen substances. Springer-Verlag, Berlin, Heidelberg. 493 p.

Jaklitsch W, Baral HO, Lücking R, Lumbsch HT, Frey W. 2016. Part 1/2 *Ascomycota*. In: W Frey (ed.). Syllabus of Plant Families: Adolf Engler's Syllabus der Pflanzenfamilien.13th Edition. Borntraeger, Stuttgart. 322 p.

Knudsen K. 2007 ["2008"]. *Acarospora*. 1–38, in: TH Nash III & al. (eds). Lichen Flora of the Greater Sonoran Desert Region. Volume 3. Lichens Unlimited, Arizona State University, Tempe, Arizona.

Knudsen K, Elix JA. 2008. *Acarospora stictica*, a new yellow species containing stictic acid, from Mexico. Opuscula Philolichenum 5: 49–52.

Knudsen K, Flakus A. 2009. *Acarospora ramosa* (*Acarosporaceae*), a new effigurate yellow species from South America. Nova Hedwigia 89(3–4): 349–353.
https://doi.org/10.1127/0029-5035/2009/0089-0349

Knudsen K, Flakus A. 2016. The identity of *Acarospora xanthophana* (*Fungi*: *Ascomycota*) and a description of *A. congregata* sp. nov. to accommodate a widely distributed saxicolous species occurring in the higher elevations of South America. Taxon 65(1): 146–151. https://doi.org/10.12705/651.10

Knudsen K, Lendemer JC. 2016. A new perspective on *Melanophloea, Thelocarpella* and *Trimmatothelopsis*: species previously placed in multiple families are united within a single genus in the *Acarosporaceae*. Bryologist 119(3): 266–279. https://doi.org/10.1639/0007-2745-119.3.266

Knudsen K, Elix JA, Reeb V. 2008. A preliminary study of the genera *Acarospora* and *Pleopsidium* in South America. Opuscula Philolichenum 5: 1–22.

Leavitt SD, Newberry CC, Hollinger J, Wright B, St. Clair L. 2018. An integrative perspective into diversity in *Acarospora* (*Acarosporaceae*, *Ascomycota*), including a new species from the Great Basin, U.S.A. Bryologist 121(3):275–285. https://doi.org/10.1639/0007-2745-121.3.275

Lumbsch T & al. 2011. One hundred new species of lichenized fungi: a signature of undiscovered global diversity. Phytotaxa 18:1–127. https://doi.org/10.11646/phytotaxa.18.1.1

Magnusson AH. 1929. A monograph of the genus *Acarospora*. Kungliga Svenska Vetenskaps Akademiens Handlingar, ser. 3, 7. 400 p.

Magnusson AH. 1940. Lichens from central Asia I. In*:* S Hedin, Reports Scientific Exped. Northwest provinces of China (the Sino-Swedish expedition). 13, XI. Botany. Aktiebolaget Thule, Stockholm. 168 p

Magnusson AH. 1944. Lichens from central Asia. Part II. In: S Hedin, Reports Scientific Exped. Northwest provinces of China (the Sino-Swedish expedition). 22, XI. Botany. Aktiebolaget Thule, Stockholm. 68 p.

Magnusson AH. 1956. A second supplement to the monograph of *Acarospora* with keys. Göteborgs Kungliga Vetenskaps- och Vitterhets-Samhälles Handlingar, ser. B, 6(17): 1–34.

McCarthy P, Elix JA. 2017. Two new species and a new record of *Acarosporaceae* (lichenized *Ascomycota*) from eastern Australia. Australasian Lichenology 80: 16–27.

Meeßen J, Sánchez FJ, Sadowsky A, de la Torre R, Ott S, de Vera JP. 2013. Extremotolerance and resistance of lichens: comparative studies on five species used in astrobiological research II. Secondary lichen compounds. Origins of Life and Evolution of Biospheres 43(6): 501–526. https://doi.org/10.1007/s11084-013-9348-z

Miadlikowska J, Kauff F, Högnabba F, Oliver JC, Molnár K, Fraker E & al. 2014. A multigene phylogenetic synthesis for the class *Lecanoromycetes* (*Ascomycota*): 1307 fungi representing 1139 infrageneric taxa, 317 genera and 66 families. Molecular Phylogenetics and Evolution 79: 132–168. https://doi.org/10.1016/j.ympev.2014.04.003

Niu DL, Wang JF, Tian XY. 2015. *Pleopsidium* Koerber—a new record genus for Ningxia with description of new record species. Acta Botanica Boreali-Occidentalia Sinica 35(8): 1697–1700.

Niu DL, Wang XY, Bu YF, Hu LF. 2017. A revision of the lichen genus *Pleopsidium* in China. Acta Botanica Boreali-Occidentalia Sinica 37(1): 191–195.

Obermayer W. 1996. *Pleopsidium discurrens*, comb. nova, newly discovered in southern Tibet. Annales Botanici Fennici 33(3): 231–236. https://doi.org/10.2307/23726264

Øvstedal D, Lindblom L, Knudsen K, Friday A. 2018. A new species of *Acarospora* (*Acarosporaceae*, *Acarosporales*, lichenized *Ascomycota*) from the Falkland Islands (Islas Malvinas). Phytotaxa 340(1): 86–92. https://doi.org/10.11646/phytotaxa.340.1.7

Prieto M, Wedin M. 2013. Dating the diversification of the major lineages of *Ascomycota* (*Fungi*). PLoS ONE 8(6): e65576. https://doi.org/10.1371/journal.pone.0065576

Reeb V, Lutzoni F, Roux C. 2004. Contribution of RPB2 to multilocus phylogenetic studies of the euascomycetes (*Pezizomycotina, Fungi*) with special emphasis on the lichen-forming *Acarosporaceae* and evolution of polyspory. Molecular Phylogenetics and Evolution 32(3): 1036–1060. https://doi.org/10.1016/j.ympev.2004.04.012

Roux C, Wirth V. 2011. *Acarospora gypsi-deserti* species nova, lichen gypsicole de Namibie. Bulletin d'Informations de l'Association Française de Lichénologie 36(2): 97–106.

Rubio C, Fernández E, Hidalgo ME, Quilhot W. 2002. Effects of solar UV-B radiation in the accumulation of rhizocarpic acid in a lichen species from alpine zones of Chile. Journal of the Chilean Chemical Society 47(1): 67–72.

Wei J C. 1991. An enumeration of lichens in China. Beijing, International Academic Publishers. 278 p.

Westberg M, Millanes AM, Knudsen K, Wedin M. 2015. Phylogeny of the *Acarosporaceae* (*Lecanoromycetes*, *Ascomycota*, *Fungi*) and the evolution of carbonized ascomata. Fungal Diversity 73: 145–158. https://doi.org/10.1007/s13225-015-0325-x